Historic, archived document

Do not assume content reflects current scientific knowledge, policies, or practices.

SHOUT
SHARE
IT

UNITED STATES DEPARTMENT OF AGRICULTURE

DEPARTMENT BULLETIN No. 1367

Washington, D. C. ▲ May, 1926

COLORING CITRUS FRUIT IN FLORIDA

By WILLIAM R. BARGER, *Assistant Physiologist*, and LON A. HAWKINS, *Physiologist, Office of Horticultural Investigations, Bureau of Plant Industry*

CONTENTS

	Page		Page
Experimental work	3	Effect of coloring on the fruit	11
Relation of temperature to rate of coloring	6	The coloring plant	14
Importance of coloring quickly	8	Coloring with ethylene	18
Methods of regulating temperatures in coloring rooms	8	Discussion	18

The advantages of coloring citrus fruit which has reached a stage of development at which it is edible and desirable for food but has not yet taken on the yellow or orange color usually associated with maturity in the minds of the consuming public are well recognized in some of the citrus-growing regions of the United States. The practice originated in California. It was first applied to the coloring of lemons and later adapted to oranges, particularly Valencias, which have a tendency to become green late in the season, even though they have once assumed the golden-yellow color. The method for lemons is described by Sievers and True,[1] who show that the coloring of the fruit is due mainly to a gas formed by the incomplete combustion of kerosene, gasoline, or some similar petroleum product, and not, as was commonly supposed, to heat and humidity. The work of these writers put the coloring of lemons on a stable basis in California, and cheap and efficient methods have been developed for the coloring of this fruit. Nearly all packing houses are equipped with some facilities for coloring. At some seasons with certain kinds of fruit, it is a very common practice and considered one of the essential operations in preparing it for market. Recently Chace and Denny[2] have shown that ethylene can be used

[1] A. F. Sievers and R. H. True. A preliminary study of the forced curing of lemons as practiced in California. U. S. Dept. Agr., Bur. Plant Ind. Bul. 232, 38 pp., illus. 1912.

[2] E. M. Chace and F. E. Denny. Use of ethylene in the coloring of citrus fruit. *In* Jour. of Ind. and Eng. Chem., vol. 11, pp. 339–340. 1924.

for the coloring of lemons and oranges, and this simplified process is being used to a considerable extent in California.

Although very commonly employed in California, the method of making green-colored but physiologically mature citrus fruits more attractive and salable was not used to any extent in either Florida or Alabama prior to 1919, when experimental work on the coloring of Satsuma oranges was begun in the latter State. In a recent publication on the results of three years' work in Alabama, Wright[3] emphasizes the fact that Satsuma oranges in that State frequently reach a stage of physiological maturity at which they are palatable and attractive as an article of diet long before they assume a golden-yellow color on the tree. He also brings out the facts that the Satsuma orange crop in Alabama is in danger of frost after November 15 and that the best market for these oranges is in the early part of the season, before they color on the tree. He showed that the method of coloring by the use of kerosene-stove gas was adapted with certain modifications for the coloring of these oranges and then determined the effect of this treatment on the marketability of the fruit. Facilities for coloring the fruit have been provided in most of the packing houses, and a considerable portion of the crop was colored in the seasons of 1921 and 1922.

In view of the conditions existing in the citrus industry in Florida and at the request of some of the most progressive and farsighted citrus growers of the State, experimental work was begun in 1920 to adapt to Florida conditions the process of coloring citrus fruit in use in California and Alabama.

The conditions in this State are somewhat similar to those in Alabama. There is a considerable acreage of Parson Brown and other early oranges in Florida, which under normal conditions ripen in the early fall while the weather is warm and usually reach their best dessert quality before taking on a yellow color on the tree. This is also true of some varieties of grapefruit, such as Davis, grown in certain parts of the State. Dancy tangerines and Valencia oranges in Florida frequently develop a high dessert quality without assuming a yellow color, and much of this fruit would never have the rich golden yellow color on the tree, although in good condition for eating, as it has a tendency to dry out if left unpicked too long.

From a careful survey of the field, apparently there was no basis for the conclusions that the color of citrus fruit is an indication of its dessert quality or attractiveness as an article of diet and that the color of the skin of the fruit when it has reached this stage in its development is partly a varietal characteristic and partly dependent upon the climatic and cultural conditions under which the fruit is grown. It is obvious, then, that treating fruit which is physiologically mature or has reached a stage in its development at which it has high dessert quality, so that it assumes a color or appearance pleasing to the eye and has a higher decorative value, is a legitimate practice in marketing and one which should be encouraged. It is, of course, also true that the coloring

[3] R. C. Wright. Coloring Satsuma oranges in Alabama. U. S. Dept. Agr. Bul. 1159, 23 pp., illus. 1923.

of fruit which has not reached the stage of development at which it is desirable for food and that consequently might be considered as artificial coloring to conceal inferiority or immaturity is reprehensible and should not be permitted.

EXPERIMENTAL WORK

The investigation proceeded along two lines, (1) testing the effect of the gas on the various types of fruit and working out methods for coloring these fruits experimentally, and (2) the application of these results to the coloring of fruit on a commercial scale. This, of course, entailed the testing of different methods of making the gas, the working out of methods of applying it, and the designing of suitable rooms and equipment. The effect of the coloring on the commercial value of the fruit was also taken into consideration.

THE GAS FOR COLORING

The gas commonly in use for the coloring of citrus fruit is made by the incomplete combustion of kerosene, gasoline, or a smiliar petroleum product. When kerosene is burned without sufficient oxygen for complete combustion, several gases are given off, among which is the gas or gases which will destroy the chlorophyll or green coloring matter in the skin of the orange without killing the cells or otherwise injuring the fruit. The yellow coloring matter present in the skin but masked by the green is evident when the chlorophyll green has been bleached out. The fruit attains an attractive yellow color. From the work of Denny[4] it seems probable that the active principle of this gas may be ethylene. He has found that ethylene can be used for the coloring of citrus fruits and has developed a process for coloring on a commercial scale with this gas.

COLORING GRAPEFRUIT WITH THE EXHAUST FROM A GASOLINE ENGINE

The first experiments carried on in Florida in this investigation were in coloring grapefruit with the exhaust from a gasoline engine. This work was done at Homestead in a small experimental room built for this purpose. The room was large enough to contain 60 standard field crates of fruit, was made practically gas tight with building paper and sheathing, and was provided with a small ventilator in the ceiling which could be closed with a slide. The exhaust from a 2½-horsepower gasoline engine was piped into the room and liberated in about the middle of the floor.

Three lots of about 60 boxes each were colored in this room in these first experiments. The first lot consisted of fruit ranging in color from 5 to 30 per cent. In coloring this fruit the engine was run intermittently for 7 to 12 hours during the daytime, and the door and ventilator were opened at night to allow the air to circulate through the fruit. A relative humidity of 75 per cent was maintained by hanging wet sacks around in the room, and 46 hours after the engine had been started the fruit ranged from 90 per cent to full color. The engine had been run 29½ hours during this time.

[4] F. E. Denny, Hastening the coloration of lemons. *In* Jour. Agr. Research, vol. 27, pp. 757–769, illus. 1924.

In the second experiment the room was filled with grapefruit which showed about the same percentage of color as the first lot, and the same plan of intermittent gas treatment and ventilating was followed as before. At the end of 29 hours, the gas having been applied for 19 hours of this time, the fruit was approximately 50 per cent colored. The engine was then stopped and the fruit held in the closed gas room 38 hours longer. At the end of this time the fruit was from 90 to 100 per cent colored and in practically the same condition as that in the first run. The lot which received the most gas reached this same color condition in 21 hours less time.

The third experiment was made with a mixed lot of sorted fruit, the entirely green being separated from the turning fruit or that showing 5 to 10 per cent color. The same procedure of intermittent gas treatment was followed in this as in the two earlier experiments. After 73 hours in the coloring room, with the engine running 31 hours of this time, the turning fruit was from 90 per cent to full color, and the fruit which was deep green when placed in the room was just beginning to take on a yellowish tinge. This last-mentioned lot of fruit was kept in the coloring room with intermittent gassing for 66 hours more, or about six days in all, at the end of which time it was about 90 per cent colored. This experiment demonstrated that it was possible to color even deep-green grapefruit but that it required a considerably longer time than that which was changing color naturally.

In the fourth experiment, a roomful of grapefruit showing 5 to 10 per cent color, as in the first two experiments, was used to test the effect of a very light concentration of the gas. The gas was applied for a period of 4 hours on both the first and second days and for 11 hours the third day. The engine was then stopped and the room kept closed. At the end of 50 hours the fruit was about 70 per cent colored, and in 39 hours more, or 89 hours in all, it was practically full colored. The buttons (short ends of stems with the calyx lobes attached) were still firm and green, in contrast to the results obtained in the first three experiments, in which they were loosened during the gas treatment and in many cases dropped out.

These four experiments demonstrated that it was possible to color early grapefruit with exhaust gases from a gasoline engine and that a good color is obtained by intermittent applications of the gas. This of course tended to give a lower concentration of the gas, with the result that the buttons remained on the fruit. The results of these experiments were applied on a larger scale in another coloring room of nearly a car capacity. In this room 300 boxes of Davis grapefruit were colored in about 72 hours by the exhaust from a 5-horsepower engine, the gas being applied about 13 hours each day. The fruit was well colored at the end of three days, and most of the buttons remained attached to the fruit after brushing. The grapefruit was in good condition when marketed. These experiments show that fruit can be colored by the exhaust from a gasoline engine and that in some cases at least this procedure would be commercially practicable. It of course involves the operation of an engine, which in most cases would run idle part of the time.

COLORING GRAPEFRUIT AND ORANGES WITH GAS FROM KEROSENE STOVES

In Florida, in most cases a common type of kerosene cooking stove with an asbestos wick is used for making the gas for coloring citrus fruit. These stoves may be put directly in the coloring room or tent with the fruit, in a pit or basement beneath that containing the fruit, or in a specially constructed room outside and at some distance from the coloring room, in which case the gas is forced through a pipe to the room by means of a fan. This method is to be recommended, as there is less danger of fire; it also furnishes a little better condition for coloring.

Experiments were carried out in houses equipped with these outside gas houses and in others with stoves in the room. These experiments were concerned with the best method of producing gas from the stove, the proper humidity for coloring, the precautions necessary in order to retain the buttons on the fruit, the temperature required for rapid coloring, and the methods of obtaining these various conditions. Most of this work was done in commercial coloring rooms attached to packing houses, but some of it was carried on in a room built expressly for this experimental work.

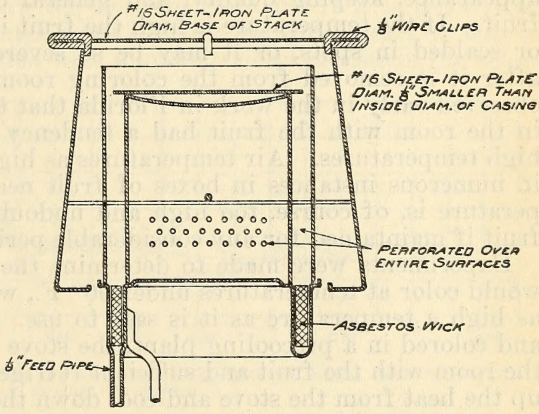
#15 Sheet-Iron Plate Diam. Base of Stack
⅛" Wire Clips
#16 Sheet-Iron Plate Diam. ⅛" Smaller Than Inside Diam. of Casing
Perforated Over Entire Surfaces
Asbestos Wick
⅛" Feed Pipe

FIG. 1.—Diagram showing the method of modifying the burner of a kerosene stove with two iron plates in order to make stove gas for coloring citrus fruit

MODIFICATIONS OF BURNER NECESSARY

In coloring the fruit it is essential that the right gas be furnished in requisite concentrations without too much heat. If combustion of the kerosene is complete, the ultimate products are carbon dioxide and water, and much heat is produced. Moreover, neither the gas nor the heat colors the fruit quickly. Coloring is brought about by gas formed by partial combustion or a partial breaking down of the kerosene induced by burning it with an insufficient supply of oxygen. Inasmuch as burners for kerosene stoves are designed to give as complete a combustion as possible, it is necessary to modify them by cutting off the air supply to the flame so that they will produce the right kind of gas for the work. After repeated trials it was found that in the method in which a metal disk one-eighth of an inch less in diameter than the cylinder was placed in the inner tube of the burner and a plate of the same material put on top, resting on bent wires, so that there was about one-sixteenth of an inch clearance between the top of the burner and the plate, the burner when lighted would produce the gas desired. These modifications are shown in Figure 1. With this burner it was found that a good proportion of the gas effective in coloring the fruit was produced with-

out the excessive heat which was yielded by complete combustion of the kerosene, though of course considerable heat is necessarily generated in this process. The method followed in modifying this burner can be adapted to other burners of different construction, for the principle involved is the same. The air supply should be cut down just as much as possible while still vaporizing the kerosene, so that the flame will be blue. If the draft is cut off too much the burner will smoke, flare up, and give off quantities of soot, resulting in a dirty appearance of the fruit without producing the desired orange or yellow color. The gas formed in this way is frequently called " stove gas," and this term will be used in this bulletin.

RELATION OF TEMPERATURE TO RATE OF COLORING

The temperature at which the fruit is held has a very important bearing upon the rate at which the fruit colors and also upon the appearance, keeping quality, and general condition of the colored fruit. If the temperature is high the fruit is liable to become brown or scalded in spots, or it may be so severely injured that its life after it is removed from the coloring room is very short. It was observed early in the work in Florida that the presence of the stove in the room with the fruit had a tendency to produce dangerously high temperatures. Air temperatures as high as 120° F. were found in numerous instances in boxes of fruit near the stove. This temperature is, of course, too high and undoubtedly is harmful to the fruit if maintained for any considerable period.

Experiments were made to determine the rate at which the fruit would color at temperatures under 90° F., which is considered about as high a temperature as it is safe to use. Fruit was cooled down and colored in a precooling plant, the stove being placed directly in the room with the fruit and sufficient refrigeration furnished to take up the heat from the stove and cool down the fruit at the same time. Inasmuch as this experiment was carried on with carload lots, it was not possible in every case to get exactly comparable fruit. The results, however, are so marked as to eliminate any error from this variation. In these experiments the temperature of the fruit as it was placed in the room was taken by means of thermometers thrust into the fruit, and temperature determinations were made in this way at intervals during the process.

Experiment 1.—Parson Brown oranges at a temperature of 80° F. were placed in a precooling room, cooled down to a fruit temperature of 40° in 48 hours, and held at that temperature until they were about 50 per cent colored, gas being applied continuously. It required six days to color this fruit.

Experiment 2.—Parson Brown oranges at a temperature of 80° F. were subjected to gas from a kerosene stove for 24 hours at 80°, at the end of which time the fruit began to show a tinge of yellow color. Refrigeration was then turned on and the fruit cooled and treated with gas at the same time. At the end of four days it was well colored.

Experiment 3.—Pineapple oranges showing 20 per cent color and having a fruit temperature of 90° F. were placed in a coloring room having an air temperature of 56°. The fruit reached a temperature of 64° F. in 24 hours and was maintained at 62° to 64° for the next

38 hours, gas from a kerosene stove being applied for the entire 62 hours. At the end of this time the fruit was approximately 50 per cent colored. The temperatures of the air and fruit in this experiment are shown in Figure 2.

Comparable lots of fruit were placed in three other coloring rooms. The first had a temperature ranging from 77° to 84° F., or about 80° on the average; the second 75° to 79°, an average of 77°; and the third an average of 78°, about the same as the second. After the gas had been applied for 36 hours to the first and second rooms, the fruit was moved out on the packing-house floor and allowed to stand 24 hours longer. At the end of that time it was about 90 per cent full color in the first or 80° room and between 80 and 90 per cent in the 77° room. The fruit in the 78° room was treated with gas for 30 hours; at the end of this time it was about 60 per cent full color.

These experiments are of interest in that they show the importance of the proper temperature for coloring the fruit if it is to be done rapidly. The experimental work, during the three years it was in progress, was supplemented with numerous observations in the color-

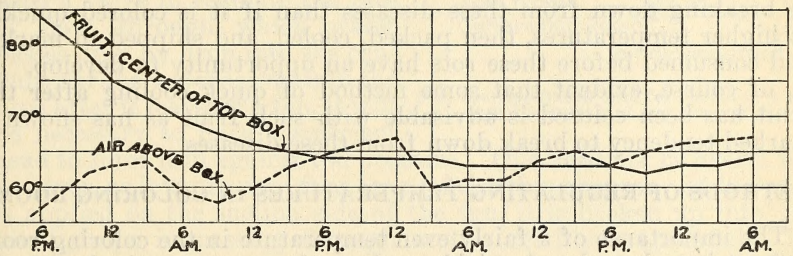

FIG. 2.—Diagram showing the air and fruit temperatures in the coloring room during experiment 3

ing rooms, showing conclusively that it required from four to five days to obtain 100 per cent orange or yellow color on fruit giving no indication of yellow when placed in the coloring room. Fruit would assume a yellow or orange color more quickly at 70° to 75° F. than at lower temperatures; at 80° to 85° oranges would show a distinct yellow color after about 36 hours continuous exposure to the gas. Grapefruit, under the latter condition, would show a marked color in 24 hours. In practice, most fruit when placed in the coloring room is partially yellow, and the time in which it can be made to assume the full yellow color is dependent to a considerable extent on the proportion of color on the fruit at the beginning. For rapidity of operation, then, it is important that the coloring room be maintained at temperatures of 80° to 85° F. It is also advisable to pick only fruit showing at least a tinge of yellow. This is particularly true for tangerines, which will not assume in the coloring room the rich, reddish orange typical of the variety, unless they have begun to color on the tree. Very good results were obtained with tangerines showing 15 to 50 per cent of color by exposing them to stove gas at a temperature of 75° to 80° F. with 85 to 90 per cent relative humidity for 60 to 72 hours.

When the weather is cold, as it is at times during the winter, it may be necessary to heat the coloring room in order to have the proper temperature. This can be done with small kerosene heaters or by heating the air in the gas-generating room by removing the plates from some of the burners and using them to heat the gas delivered to the coloring rooms.

IMPORTANCE OF COLORING QUICKLY

It is obvious that it is desirable to color fruit as rapidly as can be done without injury to its appearance or its dessert or keeping quality. If it is colored in 24 to 36 hours, a much smaller plant can be used than when it is kept in the coloring room from 48 to 72 hours, and the overhead expense will thus be greatly lessened. Another reason for making the coloring process as short as possible is the fact that much of the citrus fruit in Florida is affected with stem-end rot caused either by *Diplodia natalensis* or *Phomopsis citri*, which, according to Fulton, Winston, and Bowman,[5] will develop at temperatures above 45° or 55° F. If the fruit is colored slowly at temperatures from 60° to 75° there is much more danger of its breaking down from these diseases than if it is colored quickly at higher temperatures, then packed, cooled, and shipped to market and consumed before these rots have an opportunity to develop. It is, of course, evident that some method of quick cooling after the fruit has been colored is advisable with such fruit as has shown a marked tendency to break down from these diseases.

METHODS OF REGULATING TEMPERATURES IN COLORING ROOMS

The importance of a fairly even temperature in the coloring room if fruit is to be colored quickly and evenly was recognized early in this work, and a number of different methods of controlling temperatures were tested.

INSULATION OF COLORING ROOMS

One of the methods of partially overcoming the effect of changes of outside temperatures on the coloring rooms is insulating the room. This insulation need not be expensive, but may consist of paper and sawdust or mill shavings, which are relatively cheap and easily obtained in Florida. Double walls with paper—that is, boarding on both the outside and inside of the studding with paper next to the studding—has some insulating value, as it provides air spaces in the wall and lowers the heat leakage through it. If these air spaces, 4 to 6 inches in thickness, are filled with dry sawdust or mill shavings, the insulation will be much more efficient, and it will be much easier to keep the coloring room at an even temperature.

COOLING AND HUMIDIFYING THE COLORING ROOM

At times the temperature in Florida may be too low for rapid coloring, but it is more likely to be too high in the coloring room, so that care not to introduce too much heat with the gas is of foremost importance. One precaution against overheating the coloring

[5] J. R. Winston, H. R. Fulton, and J. J. Bowman. Commercial control of citrus stem-end rot. U. S. Dept. Agr. Circ. 293, 10 pp., illus. 1923.

rooms, which has already been mentioned, is the placing of the stoves in buildings at some distance from the coloring rooms and forcing the gas through a conduit by means of an exhaust fan. A number of determinations were made on the effect of passing the gas through conduits both above and below ground. It was found also that the air in the coloring room could be cooled by passing the gas over wet cloths or by dropping water into the conduit or into the fan used for forcing the gas into the room. This addition of water also raised the humidity of the gas which was forced into the room. The apparatus devised for dropping the water either on the fan itself or in the current of gas, shown in Figure 3, consists of a glass tube, similar to a gauge glass, fitted with a valve to regulate the rate of flow, through which water passes drop by drop into the conduit. If the water is run into the pipe after it leaves the fan, it will be necessary to have a sufficient head to force it in against the pressure. This need not be over 2 feet, however, as low-pressure fans are used for this purpose. If the water is applied on the suction side of the fan, it is broken up into very small drops in passing through and is readily evaporated. The keeping of a little water in the pipe, so that the warm gas passes over the moist surface, is also of value in cooling the gas and raising the humidity. The results of some of the experimental work on cooling the gas while conducting it from the gas room to the coloring room are shown in Table 1.

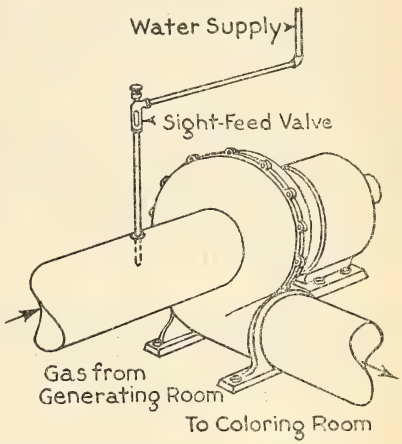

FIG. 3.—Apparatus used for dropping water into the intake of the exhaust fan

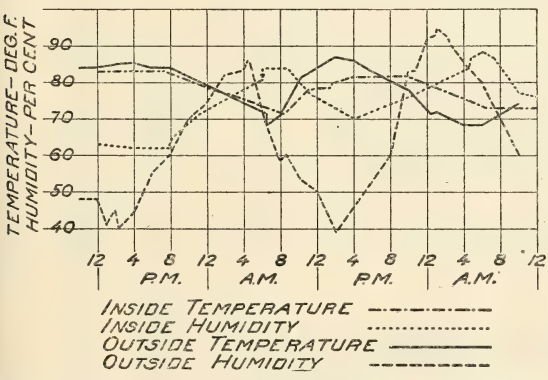

FIG. 4.—Diagram showing the temperature and humidity of the air inside the coloring room humidified by dropping water into the fan intake as compared with outside conditions

It is evident from Table 1 that passing the gas through a galvanized-iron pipe which is exposed to the sun or to temperatures about the same as those in the gas room does not cool the gas appreciably; but if the pipe is long and carried under a building where the temperature is uniformly cooler than that of the gas, some of the heat is conducted away. In cases where the pipe is buried underground, the temperature of the gas is reduced in pass-

ing through a long conduit. The mean temperature of the ground 2 feet below the surface in Florida during the early fall, when much of the coloring is done, is somewhat lower than the air temperature. Soil also conducts heat more readily than air. This explains, then, the fact, as shown in the table, that passing the gas through a buried pipe reduces the temperature more than passing it through a pipe exposed to the air. Cooling the conducting pipe by spraying it on the outside with water is of some value, but does not increase the relative humidity as much as adding water directly to the gas in the fan intake or passing the gas over the water in the pipe. The results of dropping water into the intake pipe are shown in Figure 4. There is no doubt, however, that the gas can be cooled down appreciably by passing it through long conduits either under the ground or in the shade. It is also obvious that by adding water, further cooling can be obtained and the relative humidity increased.

TABLE 1.—*Effect of forcing gas through pipe below and above ground and of adding water on the temperature and relative humidity of the coloring room with exhaust fans delivering about 1,700 cubic feet per minute*

Equipment	Temperature (°F.)			Relative humidity (per cent)	
	Outside	Entering	Outgoing	Entering	Outgoing
35 feet of galvanized rain spouting 6 inches in diameter 2 feet below ground; no water added	71	92	84	40	56
50 feet of iron gas pipe 6 inches in diameter 3 feet below ground; 100 drops of water added per minute to gas at entrance	-------	91	86	44	52
	-------	96	82	35	75
	88	91	85	40	75
100 feet same	87	109	86	40	92
	77	103	90	43	90
	84	100	87	40	85
	74	101	84	42	86
90 feet of galvanized rain spouting 6 inches in diameter above ground but under the floor; no water; temperature of air surrounding pipe 71° F	85	95	85	61	81
	85	98	89	60	87
	79	94	82	54	80
	82	92	82	37	80
	82	94	82	49	69
	76	95	73	39	78
30 feet of galvanized rain spouting 6 inches in diameter above ground; water added at entering end	88	97	98	28	61
	75	85	86	40	57
Same, except no water added	85	101	101	25	25
	80	90	89	25	25
20 feet, same; 100 drops of water added per minute at entrance	85	106	95	46	69
35 feet, same	85	106	93	46	73
50 feet, same	85	106	88	46	85
60 feet, same	85	106	88	46	85
45 feet of galvanized rain spouting 6 inches in diameter inside building and above the coloring rooms; 100 drops of water added per minute at entering end	76	80	81	72	72
	77	83	81	66	80
	82	85	83	63	76
	70	86	81	63	76
	81	88	82	61	80
	78	84	79	66	79
	72	78	77	79	87
	76	81	79	80	83
	75	82	79	80	83

Cooling the gas by refrigeration is another method used to some extent in Florida. One plant is equipped with mechanical refrigeration, passing the gas over direct expansion coils on its way from the generating chamber to the coloring room. Other plants pass the gas over blocks of ice or place ice in the coloring rooms.

With insulated coloring rooms and pipes, these methods of cooling the gas and thereby the atmosphere in the coloring room are undoubtedly effective. There is, of course, the question of cost, which must be considered in this connection, as the maintenance of a mechanically operated refrigerating plant considerably increases the overhead, while a constant supply of ice may not be conveniently available. On the other hand, burying the pipe and adding water are inexpensive, convenient, and give good atmospherical conditions in the coloring room.

TABLE 2.—*Effect of ice on the relative humidity of a coloring room 16 by 16 by 7 feet in size*

[Two 300-pound blocks of ice were placed in the room at the start, and 300 pounds were added each day thereafter]

Items of comparison	Relative humidity (per cent)		
	8 to 9 a. m.	10 to 12 a. m.	3 to 5 p. m.
In room	84.5	83.0	76.0
Outside	67.0	55.5	43.5

Tests made of the temperature obtained by the use of ice in the coloring room or by blowing the gas over ice on its way to the coloring room are shown in Tables 2 and 3. These tables also show that the relative humidity of the gas is raised considerably over that of the outside air by the evaporation of the water from the melting ice.

TABLE 3.—*Effect of ice in reducing temperature and keeping high humidity in a coloring room 16 by 16 by 7 feet in size*

[Two 300-pound blocks of ice were placed in the room at the start, and 300 pounds were added each day thereafter]

Items of comparison	12 m.	4 p. m.	8 p. m.	6 a. m.	12 m.	4 p. m.	8 p. m.	6 a. m.	12 m.	4 p. m.	8 p. m.	6 a. m.	12 m.
Humidity in room, per cent	88	92	94	94	93	90	91	93	90	90	90	94	93
Temperature (° F.):													
In room	85	82	80	77	77	77	76	76	76	77	77	75	77
Just outside room	90	89	85	72	80	82	82	74	78	85	82	74	82

EFFECT OF COLORING ON THE FRUIT

SHRINKAGE OF THE FRUIT DURING COLORING

When the fruit is received from the tree and held two or three days in a warm room, there is naturally some loss of weight due mainly to the evaporation of water from the fruit. If the humidity of the room is low there is liable to be considerable shrinkage, which may be sufficient to cause it to shrivel or the skin to dry, thus injuring the appearance of the fruit. If the humidity is between 80 and 90 per cent, however, there is very little shrinkage, as shown in Figures 5 and 6. The data from which these curves were plotted were obtained from fruit colored under commercial conditions in a

well-filled coloring room. In the operation of these rooms it is important that the humidity should be maintained high enough to prevent any excessive shrinkage, as this not only decreases the weight of the fruit but makes it less attractive.

COMPOSITION OF THE FRUIT AS AFFECTED BY COLORING

It has been stated in earlier publications on this subject that coloring apparently does not affect the composition of the juice appreciably. It is therefore important that only fruit which would pass the solids-acid test of 8 parts sugar to 1 of acid in the case of oranges

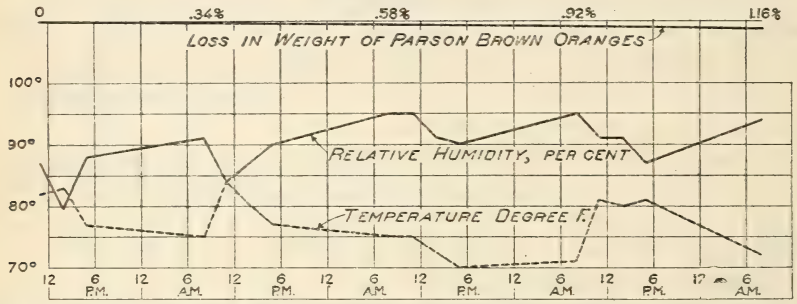

FIG. 5.—Loss in weight of Parson Brown oranges during coloring under humid conditions and at moderate temperatures

or 7 parts sugar to 1 of acid for grapefruit should be colored. Sometimes there is a change in the ratio during coloring, probably due to the evaporation of water and the concentration of juice, but it is usually slight.

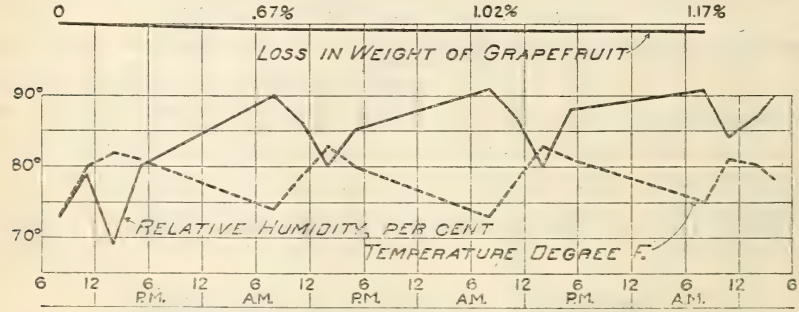

FIG. 6.—Loss in weight of grapefruit during coloring under humid conditions and at moderate temperatures

Table 4 shows the results of the solids-acid test on grapefruit before and after coloring, and in some cases on a control sample, which was a collateral lot held in the packing house for the length of time the fruit was in the coloring room. It is evident from the table that there is practically no change in the solids-acid ratio which could be attributed to the coloring process, which serves to emphasize the statement that the fruit should be of sufficient maturity to pass these tests before being placed in the coloring room. The point can not be stressed too strongly that coloring immature fruit makes it

liable to seizure in interstate shipment and that if it does happen to get on the market the sale of such fruit may result in dissatisfied customers and consequent injury to future markets.

TABLE 4.—*Solids-acid ratio in mixed common Florida and Davis (seedless) grapefruit before and after coloring*

Color stage	Citric acid	Soluble solids	Solids-acid ratio	Color stage	Citric acid	Soluble solids	Solids-acid ratio
Before coloring	1.35	9.82	7.27	Before coloring	1.55	10.82	7.00
After coloring	1.29	9.82	7.62	Do	1.49	10.75	7.21
Check (not colored)	1.24	9.75	7.86	After coloring	1.56	10.91	7.00
Before coloring	1.37	9.85	7.18	Check (not colored)	1.41	10.61	7.52
After coloring	1.33	9.82	7.38	Before coloring	1.27	9.45	7.44
Check (not colored)	1.37	9.82	7.17	After coloring	1.32	9.61	7.28

GRADING THE COLORED FRUIT

One advantage in coloring fruit is that it can be graded much more easily after it is colored than while it is still green. Defects such as branch rubs and slight scab infections are easily overlooked on fruit partially green in color, especially if the blemish is on the green surface. After it is colored these defects stand out against the yellow background. Some types of scale which are very common in Florida are loosened by the coloring process and are more easily removed in the usual operations of washing and brushing the fruit in the packing house. This also improves the grade and makes a more attractive fruit.

EFFECT OF EXPOSURE TO STOVE GAS ON STEM BUTTONS

As has already been pointed out, the loss or retention of the stem button is dependent to a large extent upon the method followed in coloring the fruit. It was shown early in these experiments that, if Parson Brown oranges or grapefruit were colored at a moderately low temperature of about 70° to 80° F., the buttons could be retained even when the relative humidity was high. The quantity of gas in the room of course has some influence on the formation of the abscission layer at the base of this stem. At the same time a large quantity of gas is usually accompanied by higher temperatures, so that it is difficult to separate these two factors. On the early fruit it was found possible to loosen this button so that it could be removed when the fruit was washed and brushed. By raising the temperature above 80° F. in a number of experiments carried on in various packing houses with this fruit these findings were corroborated, and there seems to be no question but that it is very easy to remove the buttons from the fruit by treating it from 24 to 36 hours at temperatures above 80° F. with a humidity between 80° and 90° F. With the late-season fruit, however, the buttons are not so easily removed, and late Valencia oranges, which turn green in the spring and summer, will retain them in most cases when treated at a temperature of 80° to 85° F. In the experimental work it was found that if the temperature of the room was raised to 90° or 95° F. the formation of the abscission layer at the base of the stem would be accelerated, and that the buttons could be removed from this fruit about as readily

as from fruit at the lower temperatures after 24 to 36 hours in the coloring room. It has been shown by Winston and others [6] that stem-end rot, so prevalent in Florida fruit, can be controlled by removing the buttons soon after harvesting. The work of these men has been corroborated by the writers in a number of experiments, and there seems to be no question that this disease can be controlled to a considerable extent by the removal of the buttons. It is therefore advisable in processing or coloring citrus fruit liable to be affected by stem-end rot that efforts be made to loosen the buttons during coloring. Where fruit is not affected by this disease it is of course possible that the packer may wish to keep the buttons on the fruit, which can readily be accomplished by lower temperatures and a slightly lower humidity in the coloring room.

The most convenient location for the coloring rooms is in the packing house or in a building directly connected with it. It is frequently possible to partition off a space near the washer, next to

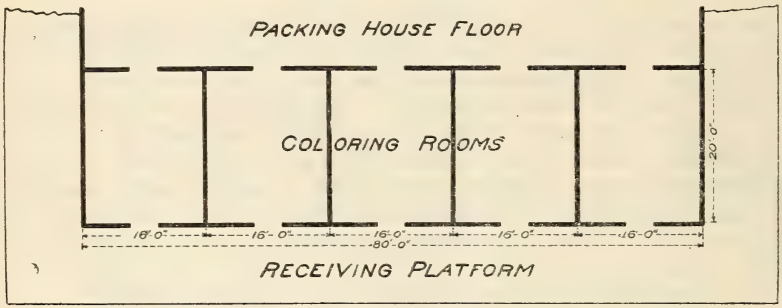

FIG. 7.—Diagram of floor plan, showing the arrangement of the coloring rooms in connection with the packing house

THE COLORING PLANT

LOCATION AND ARRANGEMENT

the receiving platform, so that the fruit can be trucked directly into the coloring rooms as it is unloaded and then trucked out to the washer after coloring. This is an economical arrangement in that it eliminates much unnecessary handling or trucking, and fruit can be stored in the coloring rooms during that part of the season when it is not necessary to color with gas. A sketch of this arrangement of the coloring rooms is shown as Figure 7.

Another plan, and one which has been followed to some extent in Florida, is to construct the rooms on either side of a corridor, one end of which opens into the packing house, the other on a receiving platform. This plan necessitates somewhat more trucking in handling the fruit in and out of the rooms than the plan just discussed, but is a convenient type of construction where more rooms are needed than can be accommodated in one tier along the end or side of the packing house. A plan of such an arrangement is shown as Figure 8.

---

[6] J. R. Winston, H. R. Fulton, and J. J. Bowman. Op. cit.

METHOD OF CONSTRUCTION

Whether the coloring rooms are of brick, cement, or frame construction, they should be insulated if an even temperature is to be maintained under the climatic conditions of Florida. This insulation may be simply a 4-inch space made by sheathing and papering both sides of the 2 by 4 studding. A more even temperature can be maintained if this 4-inch space is filled with some cheap insulation, like dry mill shavings, usually readily available in Florida. The rooms should be ceiled, and if practicable the ceiling should be insulated. A high ceiling in the rooms is of no particular advantage, and in some ways it undoubtedly is a disadvantage, as it will be more difficult to keep a constant humidity in such a room than in one with a ceiling not higher than 7 feet. Rooms should be large enough to accommodate at least one carload

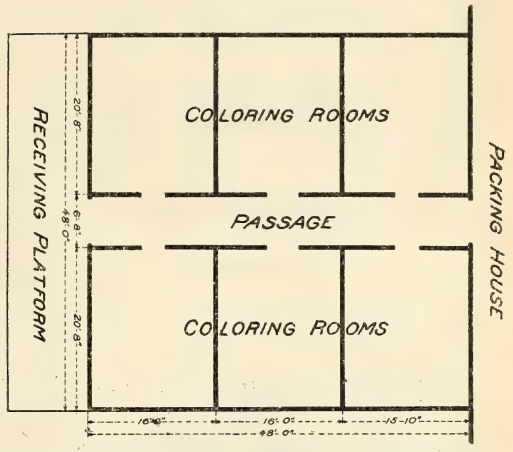

FIG. 8.—Diagram of floor plan, showing another arrangement of the coloring rooms in connection with the packing house

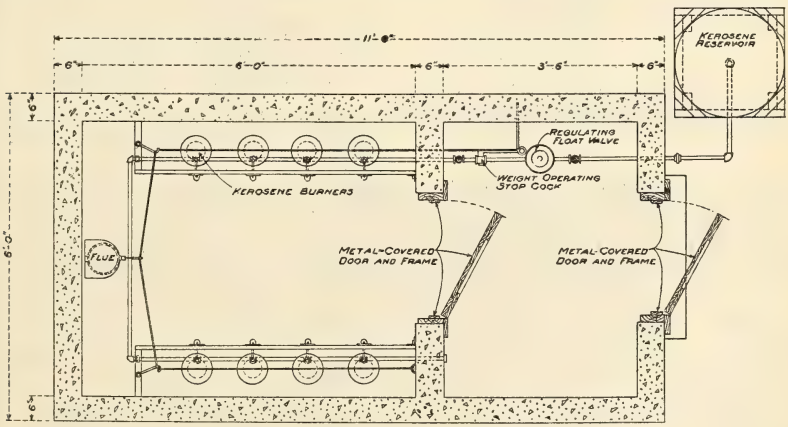

FIG. 9.—Plan of gas-generating room

of fruit conveniently. A room 16 by 20 feet will hold 400 field boxes stacked four high, which is sufficient fruit if of reasonably good grade to make a carload when packed.

As pointed out earlier in this bulletin, the stoves should be placed in a separate building, if possible, both because of danger from fire and to keep the gas delivered to the coloring room cooler. The gas-

generating room should be constructed of fireproof materials and have a fireproof roof. A plan for such a generating room is shown in Figure 9.

If for some reason it is necessary for the stoves to be in the room with the fruit or in a pit or cellar under the coloring room, they should be placed in a metal box (fig. 10) which has a removable lid that is suspended over the stove by a string. If the stove flares up the string is burned and the lid drops down with the edge in a little trough of water. The burning stove is thus inclosed in an air-tight metal box, which quickly smothers the fire.

The gas-generating room should be at a distance of 60 feet at least from the coloring rooms or packing house. The conduit for conducting the gas from the generating room to the coloring room may be of galvanized iron and should be at least 6 inches in diameter for a six-car coloring house. If the pipe is buried, tile or iron should be used. The fan for forcing the gas from the generating room to the coloring room should be of the exhaust type, located outside the generating chamber. The intake pipe to the fan should open near the ceiling of the generating room, with a damper so arranged that it will close automatically if the stoves flare up and begin to give off smoke and soot. This can be accomplished by continuing the intake pipe through the roof and cutting in it a V-shaped notch which is about the diameter of the pipe at its widest part and extends almost through the pipe. A sheet-iron damper may then be hinged at the back of the pipe and so arranged that when dropped it closes the intake pipe to the fan and opens the pipe in the roof to allow the smoke to escape and when raised opens the intake pipe and closes the pipe through the roof. This damper is held in place by a small cord which passes over the stoves and is burned through when any of the burners flare up. Details of the arrangement of the burner and damper are shown in Figure 1. If the coloring room is tight, the pipe can enter at any convenient place and the opening arranged so that the gas, which at times may be hot, will not blow directly on the fruit.

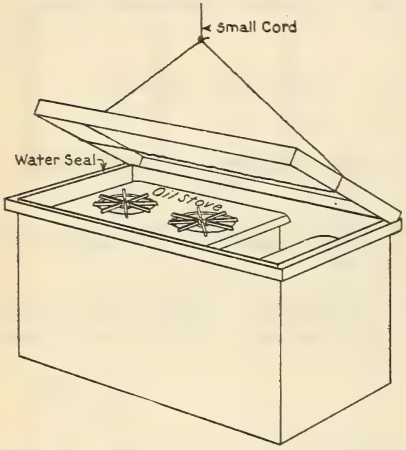

FIG. 10.—Sheet-metal box with lid suspended by a string for inclosing an oil stove when it is placed in the room with fruit

When a number of burners are used in one generating chamber, a supply tank and float valves (fig. 11) are advisable to keep a supply of fuel for the stoves at all times. When only a few burners are employed the ordinary inverted supply tank usually equipped with kerosene stoves may be used. A plan for the installation of burners and the general arrangement of the room is shown as Figure 9.

COLORING UNDER CANVAS TENTS

Canvas can be used in the construction of coloring rooms; and, if the entrance is carefully closed and the tent is tight to the ground or floor, the gas will be retained in the room and a fairly high humidity can be maintained. The temperature is, of course, uneven in such a structure, because the canvas has little insulating value and changes in the outside temperature are readily transmitted to the interior of the room. This material also is highly inflammable, making the use of stoves unsafe without placing each in a metal box such as is shown in Figure 10. Experiments in coloring under canvas were conducted in April, 1923, and it was found that it required a little more time to bring the fruit to full color in tents than in the ordinary double-walled coloring rooms. A comparison of the temperature and humidity inside and outside a canvas coloring tent during operation is shown in Table 5. In this instance the gas was supplied from an outside generating room. It is noticeable that the temperature within the tent follows very closely the outside temperature and that the humidity is inclined to be lower than is desirable for the best results.

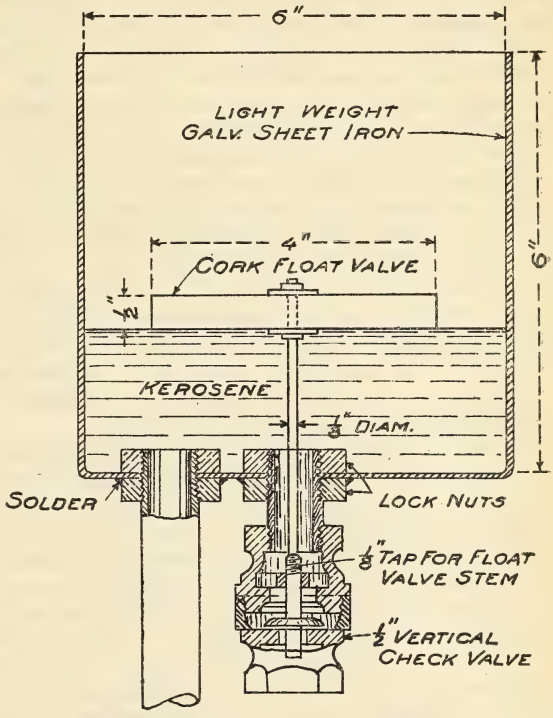

FIG. 11.—Diagram showing the construction of a float valve for the regulation of the level of kerosene in burners

TABLE 5.—*Comparison of temperature and humidity inside and outside a tent filled with fruit and supplied with gas*

Time	Temperature (° F.)		Relative humidity (per cent)		Time	Temperature (° F.)		Relative humidity (per cent)	
	In tent	Outside	In tent	Outside		In tent	Outside	In tent	Outside
7 a. m.	76	72	82	65	2 p. m.	86	88	60	46
9 a. m.	80	76	75	61	3 p. m.	87	88	57	46
10 a. m.	80	77½	75	65	4 p. m.	89	89	55	46
11 a. m.	82	80½	69	58	5 p. m.	87	87	57	45
12 m.	82	83	69	52	6 p. m.	86	87	63	45
1 p. m.	85	85	60	47	7 p. m.	80	73	83	86

COLORING WITH ETHYLENE

Considerable work on the constituent of the gas from kerosene stoves, which is the active principle in the coloring of citrus fruits, has been done by Denny,[7] and in one of his papers he points out that fruit can be colored by a number of different gases, some of which are present in the products of the incomplete combustion of kerosene. Denny showed that lemons and oranges could be colored with dilute concentrations of ethylene gas, and he, together with his associates, worked out a practical method for the application of this gas in a commercial way. The process, as described by Chace and Denny[8] is essentially as follows: Ethylene gas from a cylinder of the compressed ethylene, which can be obtained commercially, is released in the coloring room with the fruit in the proportion of 1 cubic foot of ethylene under normal atmospheric pressure to every 5,000 cubic feet of air space. The gas is released twice each day, and ventilating the rooms about an hour before each application of gas is recommended. The temperature of the room should be kept between 70° and 90° F.; 80° is preferable. The same humidity for coloring rooms as is maintained when the gas from oil stoves is used is advised. For oranges in Florida this should be about 85 per cent relative humidity.

Denny devised a tank for use with ethylene which consists of an iron cylinder of convenient size capable of withstanding 500 pounds pressure and equipped with a pressure gauge, so that the quantity of the gas released into it from the cylinder can be measured. It is necessary to calibrate the tank by releasing some of the gas into it, noting the gauge pressure, and then measuring the volume of gas delivered from the tank at ordinary atmospheric pressures. Inasmuch as the gas is inflammable and explosive when mixed with certain concentrations of air, it is important that fire should be kept away from the gas apparatus and out of the coloring room when ethylene is used. If the weather is such that it is necessary to heat the rooms to obtain the proper temperature for coloring, it should be done with steam, hot water, electric heaters without glowing wires, or some such system. In the work in Florida it was found possible to color with ethylene Valencia oranges showing 10 to 20 per cent color in 72 hours, holding the room between 70° and 80° F. with a humidity of 85 per cent. These experiments were carried on in the spring on Valencia oranges which had become green, as this variety frequently does in the late spring. Oranges in this condition are particularly hard to color. The fact that they colored up readily in 72 hours, which is about the time required for this variety with stove gas, indicates that ethylene may be a practical substitute for gas made by a kerosene stove.

DISCUSSION

In a general consideration of the accumulated data on the coloring of citrus fruits either by gases formed by the incomplete combustion of kerosene or by those of similar origin, it is evident that the process presents no particular difficulties from the operation

[7] F. E. Denny. See footnote 4, p. 3.
[8] E. M. Chace and F. E. Denny. See footnote 2, p. 1.

standpoint. It has been shown in numerous instances that this coloring does not appreciably affect the chemical composition of the pulp or edible portion of the fruit. It is therefore important that only fruit which is palatable and attractive as an article of food should be colored. It is of course well known that a yellow or orange color is not necessarily associated with maturity in citrus fruits, and that many varieties under certain climatic conditions usually reach their best eating quality when their rind is still green in color.

From the fact that the fruit does not change appreciably in chemical composition during coloring, it is evident that it should have reached such a stage of development that it will pass the test for maturity provided by Food Inspection Decision No. 182 of the United States Department of Agriculture, 1921. In grapefruit "the juice of the mature fruit contains not less than seven (7) parts of soluble solids to each part of acid calculated as citric acid without water of crystallization," and for oranges "the juice of the mature fruit contains not less than eight (8) parts of soluble solids to each part of acid calculated as citric acid without water of crystallization."

The coloring of fruit which does not meet these requirements may be interpreted as an attempt to conceal inferiority and makes such fruit liable to seizure if shipped in interstate commerce without being specifically labeled. Careful observance of this regulation is very important from a marketing standpoint, as flooding the market with immature fruit may result in a decided reaction on the part of consumers against all citrus fruit from Florida. There is a legitimate field for the application of this coloring process in Florida to fruits which from a combination of varietal characteristics with climatic conditions do not assume the orange or yellow color commonly associated with the ripe orange or grapefruit in the minds of the consuming public, but may remain green in color long after they have reached their best eating quality. If coloring is confined to these cases where it can be legitimately used it will be of considerable benefit in marketing, as it makes the fruit much more attractive and desirable in appearance, and by removing scale, makes it cleaner and easier to grade carefully.

In the experimental work which formed the basis for this bulletin, it was found that grapefruit and oranges could readily be colored by the gas formed by the incomplete combustion of kerosene in oil stoves, by the exhaust from internal combustion engines, or by ethylene. Grapefruit colors more readily than oranges, and the early oranges, such as Parson Brown, seem to assume the characteristic golden-yellow color with less treatment than do the Valencias in the spring. In this work it was found possible to color grapefruit which showed sufficient yellow color through the green to be characterized as 10 to 20 per cent colored in 18 to 36 hours. Oranges beginning to show color required from 48 to 72 hours for the early fruit. It has been shown that during coloring the removal of the buttons, or short ends of stem left on the fruit when it is harvested, very much reduces the decay from stem-end rot and can be accomplished with grapefruit by maintaining a temperature around 90° F. with a high humidity (85 to 90 per cent). If it is desired to retain the but-

tons the fruit should be colored at a lower temperature, between 70° and 80° F., with a slightly lower humidity, about 85 per cent, which will keep the fruit from appreciable shrinkage and still insure the retention of the buttons. The same holds true for oranges. If it is desired to retain the buttons the fruit should be colored slowly and at a temperature of about 70° to 80° F.; if a fruit is known to be liable to stem-end rot and it is desired to remove the buttons it can be accomplished by coloring it at a higher temperature and with a high humidity. At a temperature of 70° to 80° F. and a humidity of 85 per cent, it will require about three days to bring Parson Brown oranges showing some color when placed in the room to nearly full color, whereas at high temperatures the same results can be obtained in a somewhat shorter time. In these recommendations it must be remembered that the time element is not exact, as much depends upon the condition of the fruit when placed in the room. If the fruit shows no yellow color on the surface, it takes considerably longer to bring it to a full golden yellow than if the yellow color shows through the green on the fruit. Late Valencias are somewhat harder to color than grapefruit or early varieties of oranges, and in our experiments it has been found that it requires about 70 to 96 hours to color this fruit if the temperature is held around 90° F. with a humidity of about 85 per cent. Removing the buttons from Florida fruit is to be recommended in most cases, as there seems to be no doubt that this treatment will considerably reduce the occurrence of stem-end rot in transit or on the market. Produce dealers may raise some objection to this practice, because fruit with the buttons removed is regarded as "drops," fruit which has fallen from the tree, the shipping of which is, of course, not practiced to any extent. But if it is shown that fruit is less liable to decay with the buttons removed, the trade will adjust itself to these conditions.

In the coloring of oranges with gas, it is important that the burners of the stove be so arranged that they give off a large quantity of gas with as little heat as possible. Two burners, properly regulated, should furnish enough gas for the coloring of a carload of fruit. Care should be exercised to see that the humidity is as nearly constant as possible, and various methods of humidifying the room can be used, as, for example, sprinkling the floor of the coloring room with water, dropping water into the intake of the fan, or forcing the gas through a humidifier. Very good results were obtained in these experiments by simply dropping the water into the intake of the fan. One very important consideration is that the temperature of the room should not be allowed to go above 90° F., as there would then be danger of injury to the fruit. Low temperatures can be obtained more easily in insulated houses with the gas-generating apparatus in a separate building at some distance from the house, conducting the gas through buried pipes to the coloring room. If precautions are taken to keep the proper temperature and humidity and to supply the right kind of gas to the coloring room, no difficulty should be experienced in successfully coloring oranges, tangerines, or grapefruit.

○